

FINAL PERFORMANCE REPORT

VISUALIZATION AND ANIMATION IN CIVIL ENGINEERING Award F49620-01-1-0539

**Principal Investigator
Dr. Howard Turner P.L.S.**

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Building 17, Room 1671 at California State Polytechnic University Pomona, an 1800 sq ft. laboratory, houses the 25 Dell 530 workstations acquired. Each computer is equipped with a stereographic emitter, a trackball and a Wildcat 5110 video card to perform softcopy photogrammetry, stereo visualization, and animation.

The civil engineering curriculum has been modified to include visualization and animation concepts into lower and upper division courses. Rhino-3D, a simple 3d modeling tool, was added to the freshman CAD class. The resources leveraged from this grant, more than \$7 million, allowed the curriculum to be modified. A new course CE 420 Digital Mapping was added to the curriculum. This new course focuses on 3D data collection, modeling, visualization and animation.

In the one year performance period, approximately 120 freshman and 50 senior students from under represented groups have been exposed to visualization and animation concepts. The total number of students exposed to these concepts is approximately 270. As the project develops and grows, it is anticipated that more than one thousand students will be exposed, through course expansion, faculty workshops, and high school visits in this state-of-the-art laboratory.

15. SUBJECT TERMS

VISUALIZATION, ANIMATION, CIVIL ENGINEERING, COMPUTER MODELING, STEREO

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Objectives

Civil engineering students frequently have difficulty understanding concepts and problems, such as statics and dynamics that involve 3-D space. Visualization and animation are areas of increasing importance in civil engineering practice.

The goal of this proposal is to adapt concepts developed in the Graphics, Visualization and Usability Center at Georgia Institute of Technology, and to implement a modification of these concepts into the civil engineering curriculum at Cal Poly Pomona. The initial objective is to introduce real-time visualization and animation into upper division courses. A second concurrent objective is to introduce static 3-D visualization into freshman and sophomore classes.

Objective one will be accomplished by acquiring 20 graphics accelerated SCSI workstation with static and dynamic visualization software. This equipment will be used to modify the photogrammetry and GIS classes. Data are collected in these classes by softcopy photogrammetry. These data will be used to build computer models with visualization and animation software currently applied in industry. Students will develop terrain fly-through, building walk-through, earthquake simulations and civil engineering equipment simulations. Concurrently, this equipment will be used in senior projects and the comprehensive civil engineering design classes.

Objective two will be accomplished by acquiring a lab license for *Rhinoceros*, a 3-D NURBS solid modeling and static visualization tool. Static visualization concepts will be introduced into CE 127 CAD Engine Concepts, a freshman computer graphics class. More advanced concepts will be addressed in CE 210 Computers in Civil Engineering, which is a sophomore civil engineering computer class. This software will operate on existing computers.

The goal of the project will be met in the third year of the project by extending the knowledge gained by participants into other courses in the curriculum, such as CE 222 Highway Engineering Design, CE 223 Transportation Engineering, CE 480 Advanced Highway Design, and CE 406 Structural Design of Steel.

This project addresses both upper and lower division audiences. Approximately 33% or 175 students who are underrepresented minorities will be impacted by this project. In addition, the College of Engineering works with a consortium of high schools, and the civil engineering department works with MTA Foundation and its transportation academies. Several hundred high school students will be educated by this project.

In addition to this diversity theme, this proposal integrates new technology into the curriculum of the Department of Civil Engineering in a way that will improve student learning and understanding of three-dimensional space.

Equipment Acquired

- A. Dell 530 Workstations with Dual Intel Xeon 1.8GHz. processors with 1GB memory with 3D Labs 5110 video card, 3COM 10 / 100 Network Ethernet card, internal CD/RW 40X/12X/40X, sound card, two IDE hard drives, one 40GB, one 80GB, 2 serial, 1 printer and 2 USB ports, US keyboard, Mouse, Speakers, Windows 2000 operating system, and 3 years on site next day response warranty, parts and labor (Quantity 30).
- B. Dell 19" Color Multi-Sync Monitor (Quantity 30).
- C. Stereographics EZ Emitters (Quantity 30)
- D. ITAK Mouse-Trak Professional Trackball (Quantity 30)
- E. 5 - Pack Stereo Eye Glasses (Quantity 2)

Explain Funds Used

Items A and B	DOD Grant F49620-01-1-0539	\$76,421.00
	NSF Grant 01-26874	\$20,571.02
	Cal Poly Non Federal Funds	\$ 9,233.70
	Total Cost	\$106,225.72
Item C	Cal Poly Non Federal Funds	\$ 5,400.00
Item D	Cal Poly Non Federal Funds	\$ 4,020.00
Item E	Cal Poly Non Federal Funds	\$ 1,845.00
Total Cost of Equipment in Laboratory		\$117,490.72

Matching Funds

Donation of 25 licenses of Bentley Systems Inc. Visualization and Animation Software \$270,000, described as follows in the Bentley Catalog:

Bentley Enterprise Navigator can increase the value of engineering and enterprise data by making it visible to all project participants. It is an ideal tool for real-time, interactive, intelligent 3D model review for the plant and building industries. It provides features for visualizing and querying both graphical and non-graphical information from many industry-standard applications.

Bentley Schedule Simulator lets users "virtually" build a facility according to a construction schedule. Modifications to the schedule can be easily reflected in the

simulation, and users can also choose to play multiple scenarios, such as early vs. late start or actual vs. planned progress.

Bentley Dynamic Animator takes static models generated in the design phase of a project and applies accurate motion to the 3D objects. Animations can easily be recorded, replayed, and modified as required, and can be output to video files for presentation or training purposes. Automated clash-detection highlights proposed movement conflicts, enabling early problem resolution

Cal Poly Non-Federal Funds used to by additional Computers \$9,233.70

Additional Support Incorporated in Laboratory (not declared as matching)

25 licenses of BAESystems Softcopy Photogrammetry and Visualization software	\$2,900,000
25 licenses of Intergraph GIS and Visualization software	\$1,447,625
30 licenses of Z/I Imaging Softcopy Photogrammetry and Visualization Software	\$2,400,000
Trimble GPS & Surveying hardware and software	\$ 700,000

Total Investment in Laboratory for Visualization and Animation **\$7,835,115.72**

Status of Effort

Building 17, Room 1671 at California State Polytechnic University Pomona, an 1800 sq ft. laboratory, houses the 25 Dell 530 workstations acquired. Each computer is equipped with a stereographic emitter, a trackball and a Wildcat 5110 video card to perform softcopy photogrammetry, stereo visualization, and animation.

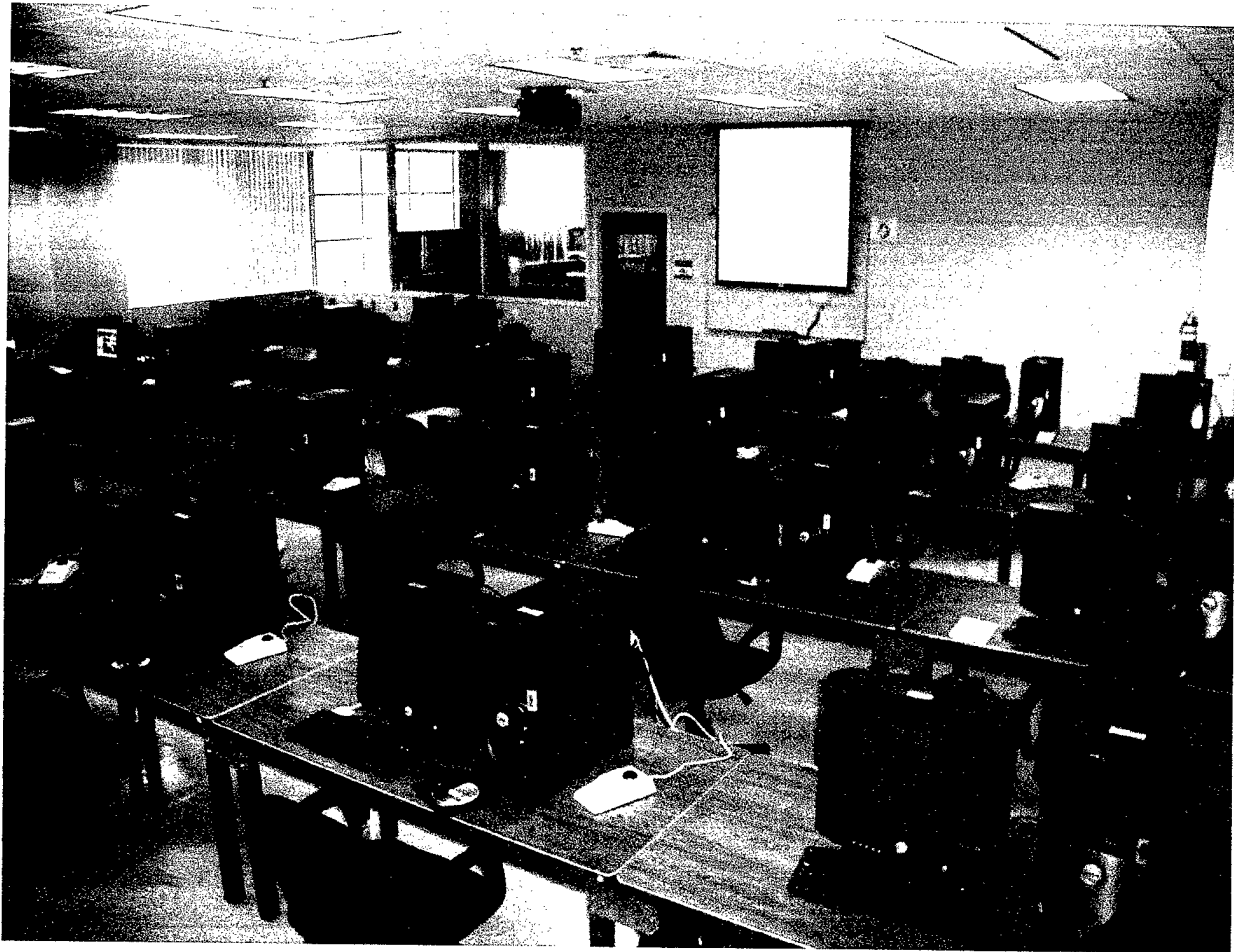
The civil engineering curriculum has been modified to include visualization and animation concepts into lower and upper division courses. Rhino-3D, a simple 3d modeling tool, was added to the freshman CAD class. The resources leveraged from this grant, over \$7 million, allowed the curriculum to be modified. A new course CE 420 Digital Mapping was added to the curriculum. This new course focuses on 3D data collection, modeling, visualization and animation.

In the one year performance period, approximately 120 freshman and 50 senior students from under represented groups have been exposed to visualization and animation concepts. The total number exposed to these concepts is approximately 270. As the project develops, it is anticipated, that several hundred students will be exposed through course expansion, faculty workshops, and high school visits in this state-of-the-art laboratory.

Accomplishments

The 25 units of the equipment acquired under this grant are housed in Building 17, Room 1671 at California State Polytechnic University Pomona. Room 1671 is an 1800 sq ft. laboratory shown

below. Each computer is equipped with a stereographic emitter and a Trackball to perform softcopy photogrammetry and stereo visualization and animation.



Five additional units were acquired, two are in the offices of faculty responsible for this project, one is with the technician responsible for helping students during laboratory sessions, one is with the systems administrator responsible for maintaining the system, and one is in the dedicated research laboratory for this project. It is used as the master machine to ghost the others to minimize laboratory down time.

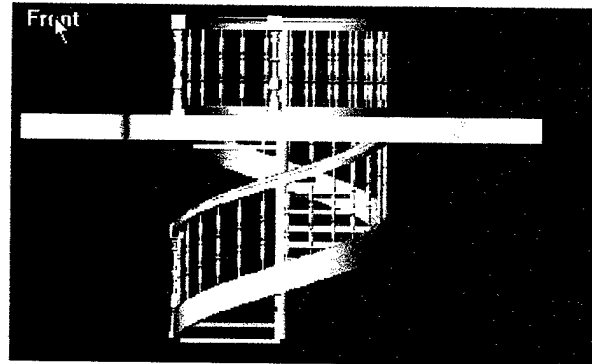
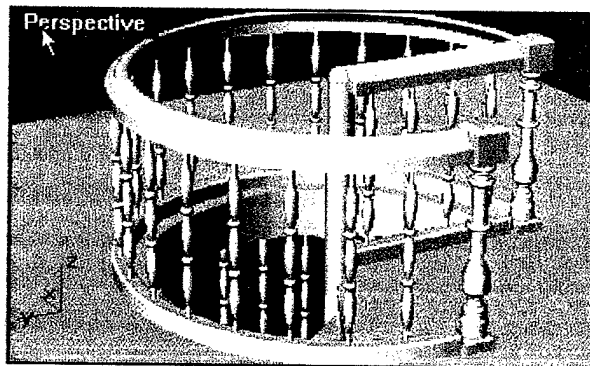
It was proposed to initially educate upper-division civil engineering students in the theory and practical aspects of data capture, visualization and animation relevant to civil engineering practice. Concurrently, simple visualization tools would be introduced into freshman and sophomore classes. It was originally proposed to modify the photogrammetry and GIS classes to begin the upper division implementation. This was attempted, but it was discovered that students were lacking training in fundamental concepts of 3D modeling and visualization. Even though students completed the 3D exercises in photogrammetry and GIS easily, they had difficulty extending to rendering and visualization. It was determined that students had difficulty in distinguishing between solids and surfaces, and had little or no knowledge of the difference.

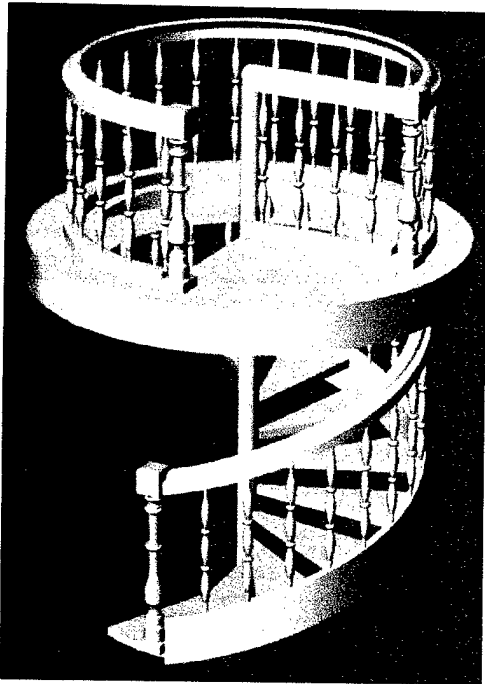
However considerable resources were leveraged from the initial DOD grant of \$76,421. The National Science Foundation partially funded the project for \$75,081, and industrial partners, BAE Systems, Bentley Systems, Intergraph, Trimble Navigation, and Z/I Imaging contributed resources valued at several million dollars. This donation of equipment and software generated the need for curriculum change. A new course CE 420 Digital Mapping was added to the curriculum to teach students modern 3D data collection techniques, 3D modeling, visualization and animation concepts. The curriculum for the new course is shown in Appendix I.

The following is a detailed description of the curriculum changes that have been made in the performance period.

CE127 – CAD Engine Concepts: (Fall 2001, Winter 2002, Spring 2002, Fall 2002)

Students learn 2-D MicroStation in this class. In the last year, the class has been modified to include Rhino-3D, a simple 3-D NURBS modeling tool. Rhino was used in this course for the first time in December 2001. Nine (9) hours were allocated for 3D design with Rhino. Rhino was introduced as a continuation of CAD design using MicroStation. Students were given basic instruction on the use of Rhino using the three tutorials that come with the software. Students then completed a more elaborated project to further enhance their visualization skills. This consisted of the drawing of a staircase using a tutorial that is available at <http://www.geocities.com/rhino3dtutorials/SpiralStairCase/>. This manual is in Appendix II. The final staircase is shown in the following images.

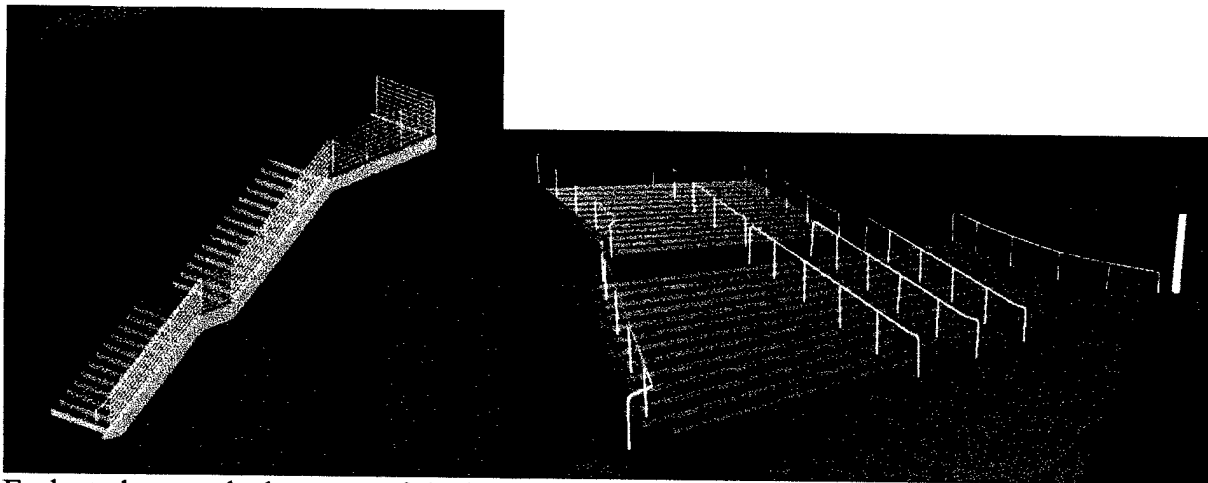




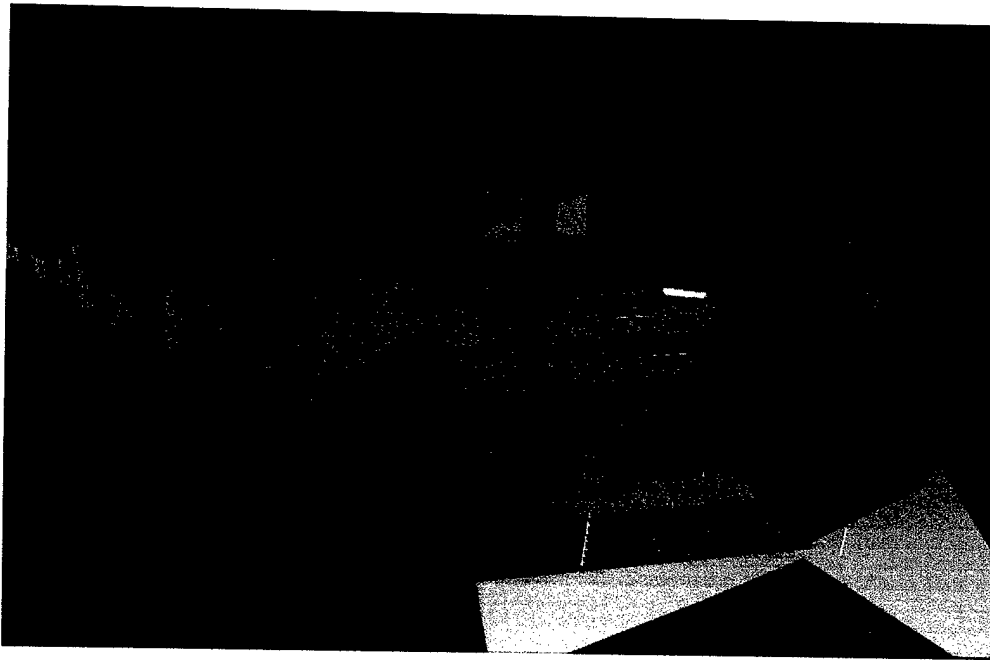
Rhino proved to be a very easy tool to teach 3D design, rendering and visualization in a short period of time to students that were dealing with 3D design for the first time.

CE499 Visualization Trial Course (Spring Quarter 2002)

In spring quarter 2002, a trial course was developed to examine the problems encountered by introducing visualization and animation into a civil engineering curriculum. It was decided to combine data collection with visualization, and initially avoid animation. Eighteen students enrolled in this class. An alumnus of the civil engineering program owns "The Prizm Group," a Geospatial engineering company. The Prizm Group owns a Cyrax Scanner. This scanner was used to scan the exterior of the engineering building. Students modeled the exterior of the building using Cyrax software that was loaned to the university. The results are shown below.



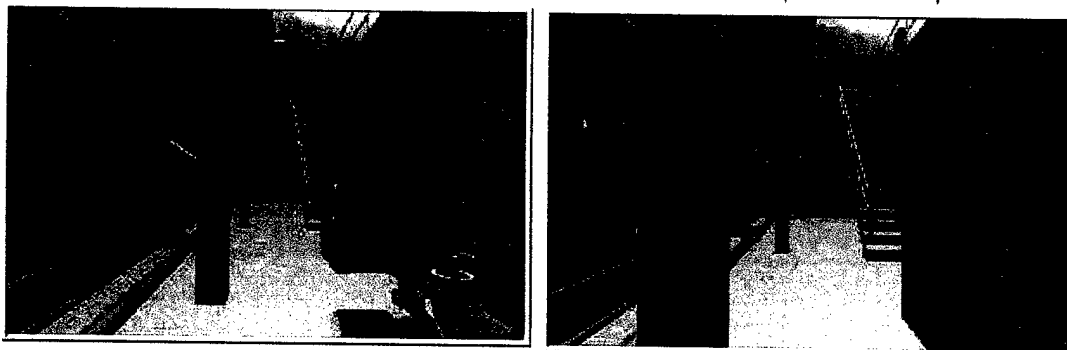
Each student worked on part of the building, and a composite was generated from student work which is shown below.



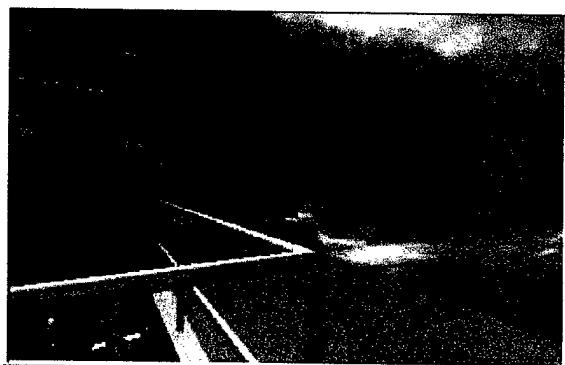
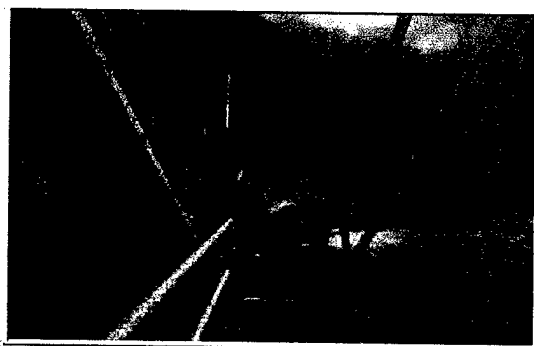
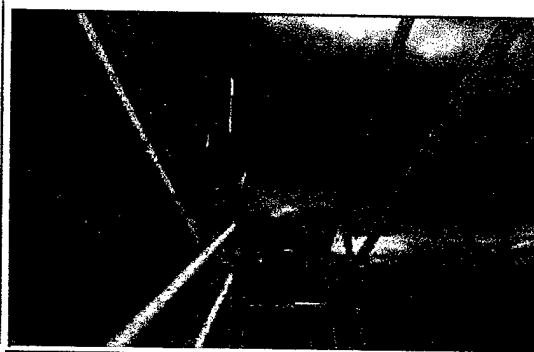
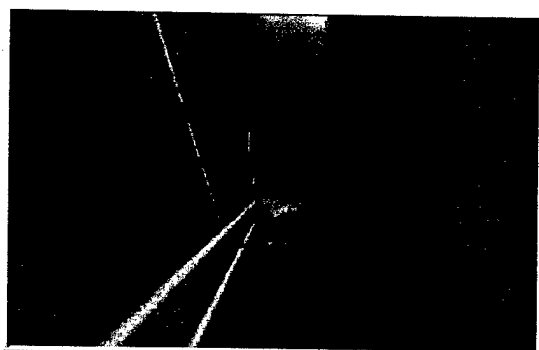
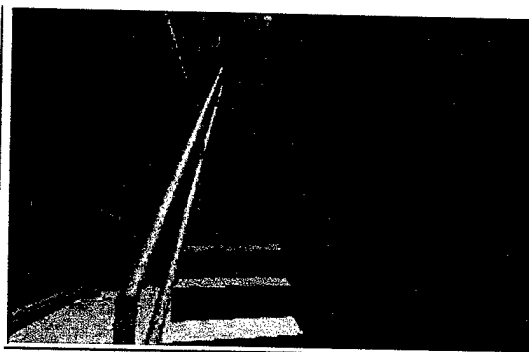
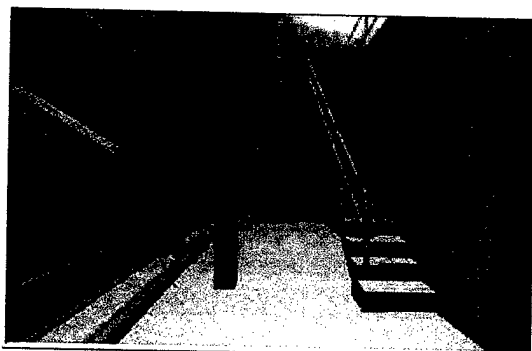
A valuable lesson was learned during this course. Modeling requires complex graphic elements which are connected. Data collected by students is frequently below the required quality because they are learning the data collection process at the same time. Results showed that students would learn visualization and animation concepts better if the data they were working with was of good quality.

CE499 Visualization Trial Course (Fall Quarter 2002)

A second trial class was offered in the fall quarter 2002. Twelve students enrolled in this class. Students spent the first 6 weeks learning 3D modeling, visualization and animation techniques with Bentley software. In the remaining weeks, they were given a project of modeling a walk-through or fly-through of the Saugus treatment plant of the Los Angeles County Sanitation District. This time the data was collected by professionals and was of good quality. The images below are screen shots of the walk-through and the video is included as part of the report.



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The course was more successful and the students accomplished more. Knowledge gained from these trial courses was used to develop a new course CE 420- Digital Mapping. This new course will include data collection, modeling, visualization and animation. However, students will not model the data they collect. They will model good quality data collected by professionals. The course outline is shown in Appendix I.

Conclusion

Funding obtained under this grant was used to purchase computers for the Geospatial Engineering Laboratory. This funding was leveraged into partial support for the project from the National Science Foundation, and several industrial partners. Donations from industrial partners allowed the Department of Civil Engineering to introduce a new course into the curriculum to teach students concepts of 3D modeling, visualization and animation. As the project grows, and students become knowledgeable in these techniques, they will include them in senior projects, comprehensive design projects, and the workplace when they graduate. Cal Poly Pomona will graduate at least 120 students each year, most of them American citizens, most of them from under represented groups, knowledgeable in visualization and animation techniques, who will be available to the Department of Defense and its contractors for work necessary for national security. This project is partially funded by the National Science Foundation and we will continue to report to the Air Force Office of Scientific Research as we report to the Foundation.

Personnel Supported

Dr. Francelina Neto

Publications

None

Interactions/Transitions:

a. Participation/presentations at meetings, conferences, seminars, etc.

Title

Geospatial concepts in visualization and animation curriculum development

Accepted for presentation at The International American Society of Photogrammetry and Remote Sensing (ASPRS) 2003 Annual Conference "Technology: Converging at the Top of the World", May 5-9 at the William A. Egan Civic and Convention Center in Anchorage, Alaska.

Authors

Dr. Howard Turner, & Dr. Francelina A. Neto, Professors, Dept. Civil Engineering, California State Polytechnic University, Pomona

Abstract

Engineering students at California State Polytechnic University Pomona have in the past had difficulties in visualizing concepts in 3D. Some time ago, the civil engineering department developed a CAD course for freshmen. However, this course did not provide enough visualization concepts to properly prepare the students for the complexity of some of the more advanced disciplines. The authors received one grant from the Department of Defense, and another from the National Science Foundation, which complement each other, for curriculum development in 3D visualization and animation concepts. As part of the referred grants, geospatial concepts are adapted to several disciplines in various areas of engineering, to introduce visualization and animation techniques to the students. The advantages of understanding spatial concepts, visualization and animation techniques have been recognized on campus. The idea was developed one step further in order to be introduced outside the engineering discipline. The University Senate and Curriculum Committee just approved a new, elective general education course on elements of spatial techniques, for a wide-ranging, diverse audience. In this course, geospatial, surveying, visualization and animation will be introduced with applications to natural sciences and arts and letters students. The paper describes the concepts and various curriculum developments.

b. Consultative and advisory functions to other laboratories and agencies, especially Air Force and other DoD laboratories.

None

c. Transitions. Describe cases where knowledge resulting from your effort is used, or will be used, in a technology application. Transitions can be to entities in the DoD, other federal agencies, or industry.

None

Briefly list the enabling research, the laboratory or company, and an individual in that organization who made use of your research.

None

New discoveries, inventions, or patent disclosures. (If none, report None.)

None

Honors/Awards:

None

APPENDIX I New Course Curriculum

CALIFORNIA STATE POLYTECHNIC UNIVERSITY, POMONA

COLLEGE OF ENGINEERING

SURVEYING CORE CURRICULUM COURSE OUTLINE

I. Catalog Description

Title: CE 420/L Digital Mapping (3/1).

Robotic and Reflectorless Total Stations, Lidar Scanning and GPS for digital mapping applications. Projections. Solid and surface modeling tools and theory. 3D models to shorten design cycles, visualizations, interference checking and interchangeability. Models to create virtual reality designs using materials, and lighting. Rendering techniques and animation. Fly Through, keyframe, parametric and hierarchical animation. 3 lecture/problem solving. 1 three-hour laboratory.

II. Required Background or Experience

Upper division standing; CE 127/L and CE134/L.

III. Expected Outcomes

Students should, on completion of this course, be able to demonstrate:

- i. Knowledge of Geospatial engineering data collection, processing and modeling using reflectorless and robotic EDM.
- ii. Knowledge of Geospatial three-dimensional systems, and the ability to apply this knowledge in engineering practice.
- iii. An understanding of the use and theory of the different components of modeling, visualization and animation systems.
- iv. Ability to design Geospatial modeling, visualization and animation systems and make rational management decisions on the implementation these systems in engineering practice.

IV. Text and Readings

Texts: Samir Haque et al. Adventures in MicroStation 3D, Onword press, 1996
www.delmar.com

Web Resource Readings: <http://www.csupomona.edu/~hturner/ce420.html>

V. Minimum Student Materials

Pen, paper, notebook, class notes, electronic calculator and assigned text.

VI. Minimum College Facilities

The class requires a smart classroom with computerized audio-visual equipment, internet access, access to university library, a standard whiteboard and 25 computer workstations.

VII. Course Outline

Lecture

- i. Data Collection Techniques, GPS, Robotics, Reflectorless EDM, Scanning
- ii. Data Processing and Modeling Techniques
- iii. Projections
- iv. Solid and Surface Modeling
- v. Materials and Rendering
- vi. Lighting and Camera
- vii. Animation

Laboratory

- i. GPS Mapping
- ii. Robotic Total Station Mapping
- iii. Reflectorless EDM mapping
- iv. Lidar Mapping
- v. Projections
- vi. 3D Modeling
- vii. Rendering
- viii. Animation
- ix. Design Project
- x. Design Project

VIII. Methods of Instruction and Evaluation

Class format integrates lectures and laboratory assignments, student presentations with a critical writing assignment and critical evaluation of a project. Students are required to take mid-term and final examinations and design an original real-world project. Students are required to research, collect, process and model real-world data.

IX. Evaluation of Outcomes

Students are evaluated with respect to course material through mid-term and final examinations, project evaluation with report and presentation.

Assessment

There are various methods used to assess the course. The following are some of the methods used:

- I. Grading of student work
- II. Civil Engineering Department course assessment surveys
- III. Outside reviews of course content by the Civil Engineering Industrial Action Council.
- IV. Outside reviews of course content by the Accreditation Board for Engineering and Technology (ABET).
- V. Outside reviews of course content by Bentley Civil Engineering Advisory Board.
- VI. Internal review of course content by the Civil Engineering Department Curriculum Committee


APPENDIX II

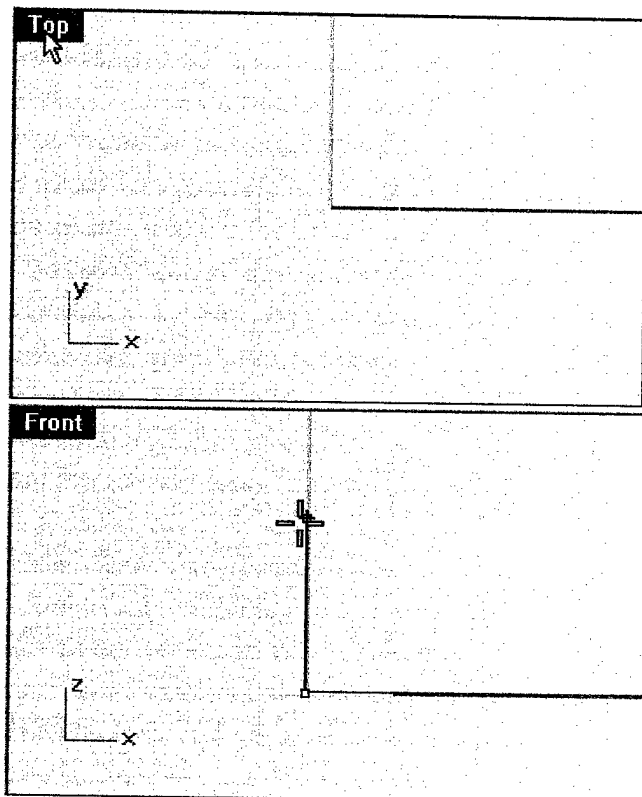
Rhino 3D Exercise


How to make a Spiral Staircase - Manual

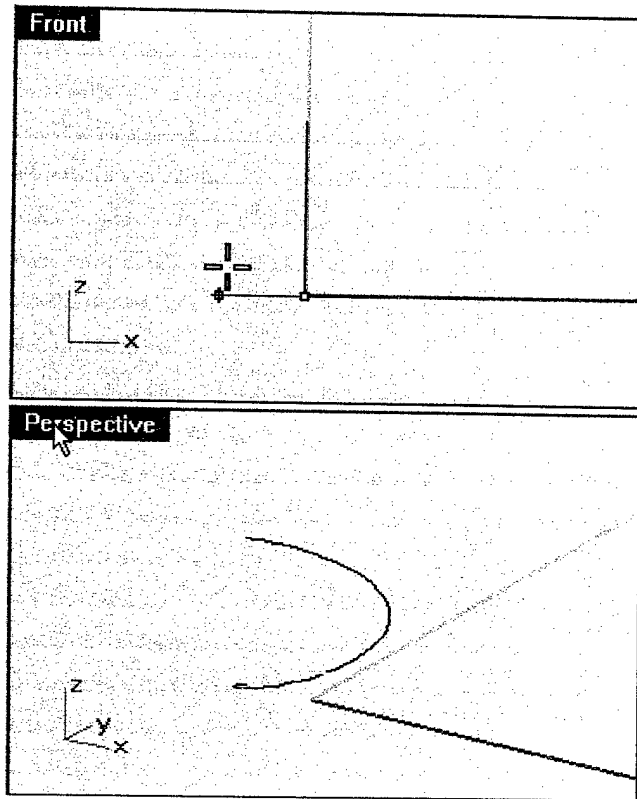
This manual is on-line at <http://www.geocities.com/rhino3dtutorials/SpiralStairCase/>.

In this project you will be using Array a lot. This is a very useful function. The purpose here is to give you an idea of the mechanics and then you can do your own designs.

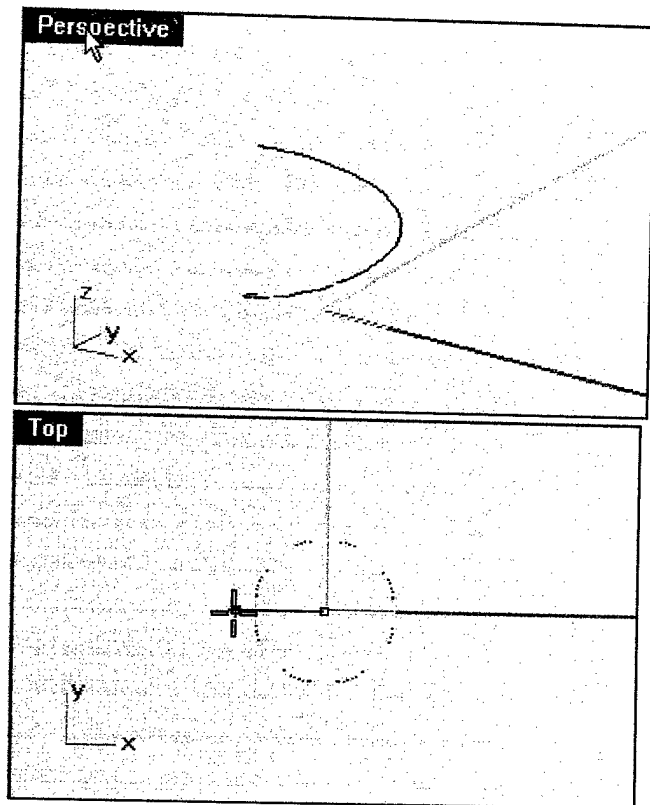
First to make is a step, create a Circle  as shown. 4 unit rad.



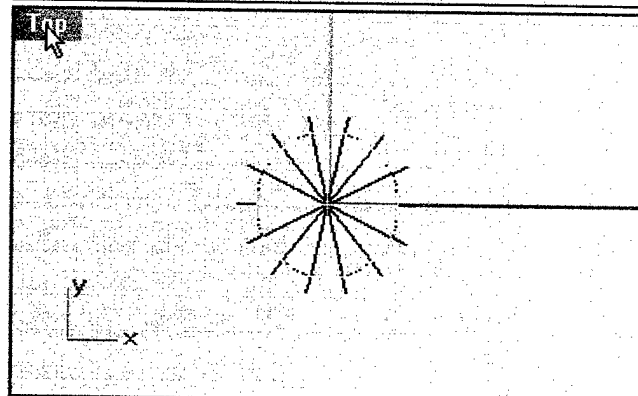
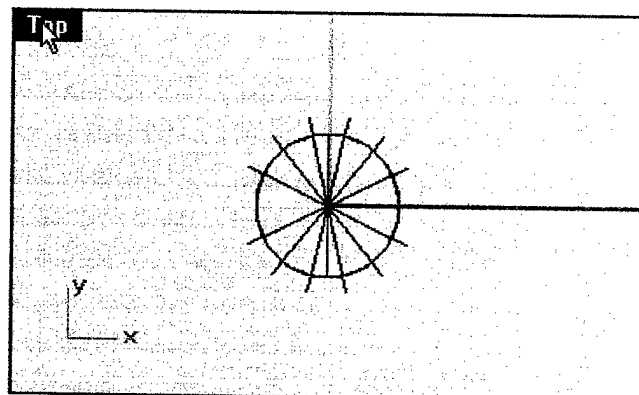
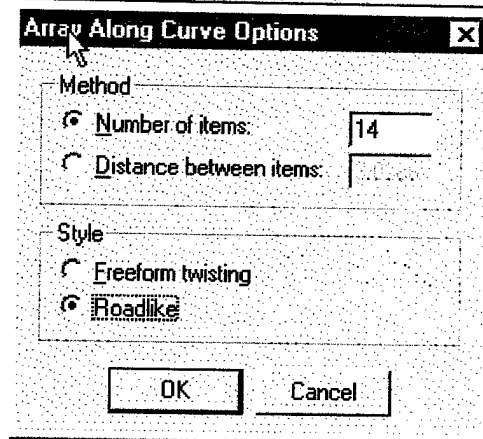
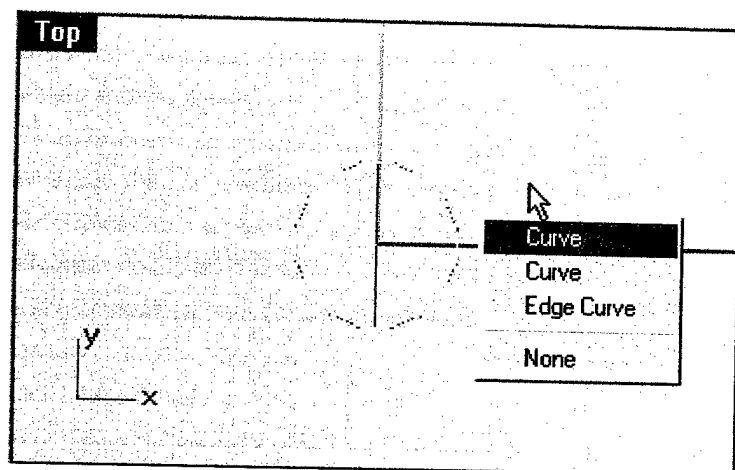
Next create a Curve/Helix , same radius and 8 units high, and one turn.




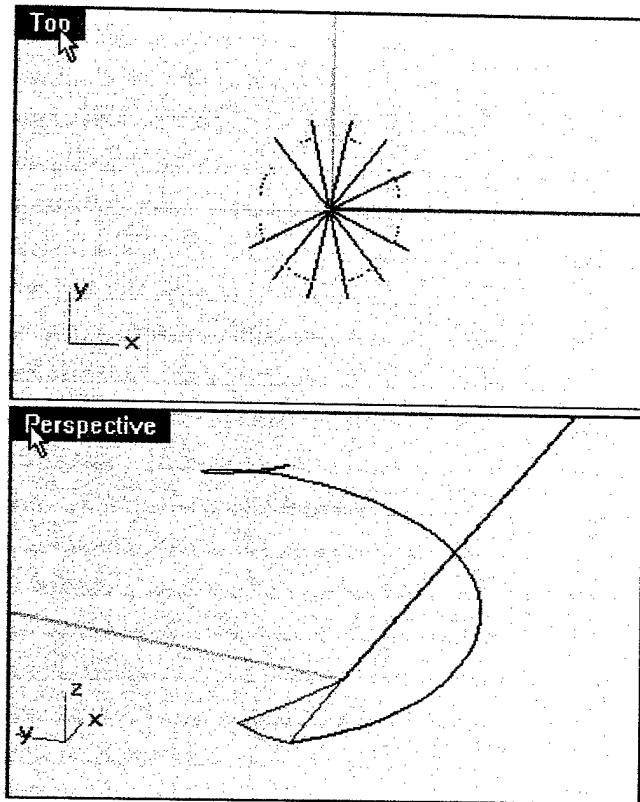
Next use Surface from Planar Curves to create a surface from the circle. Next create a Line Segment  from the center to the side.



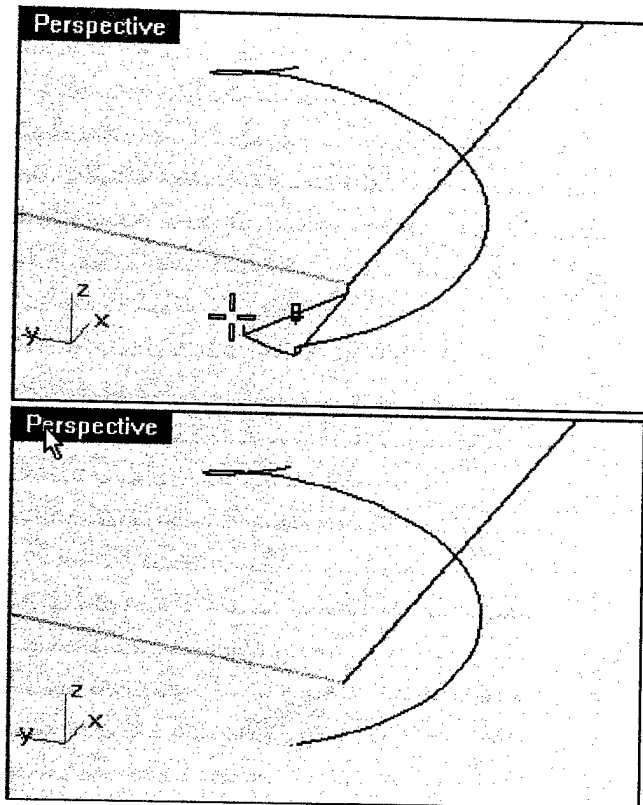
Now use Transform/Array/Along Curve to multiply the line segment 14 times. Make sure you have "Style" "Road like" selected.



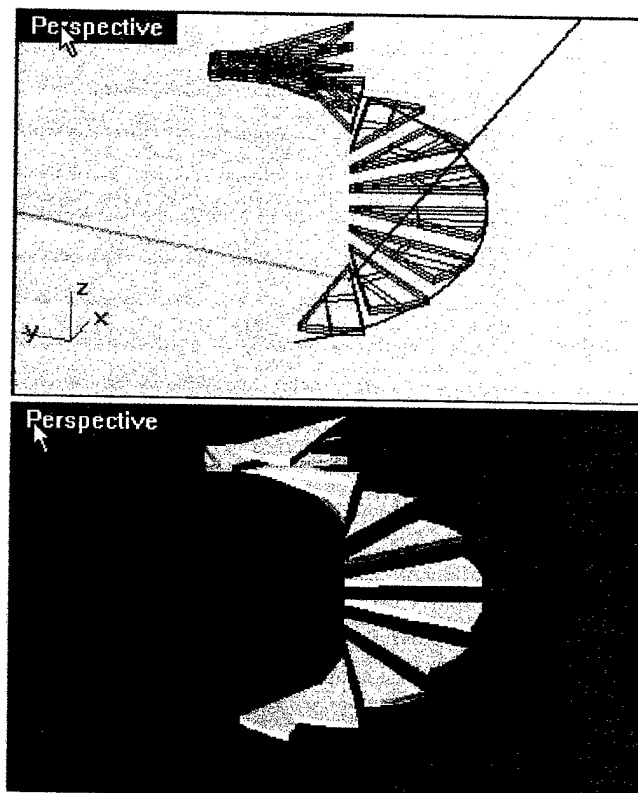
Now Split  the surface with the lines selected. This will give you a pie segment that will be your step.



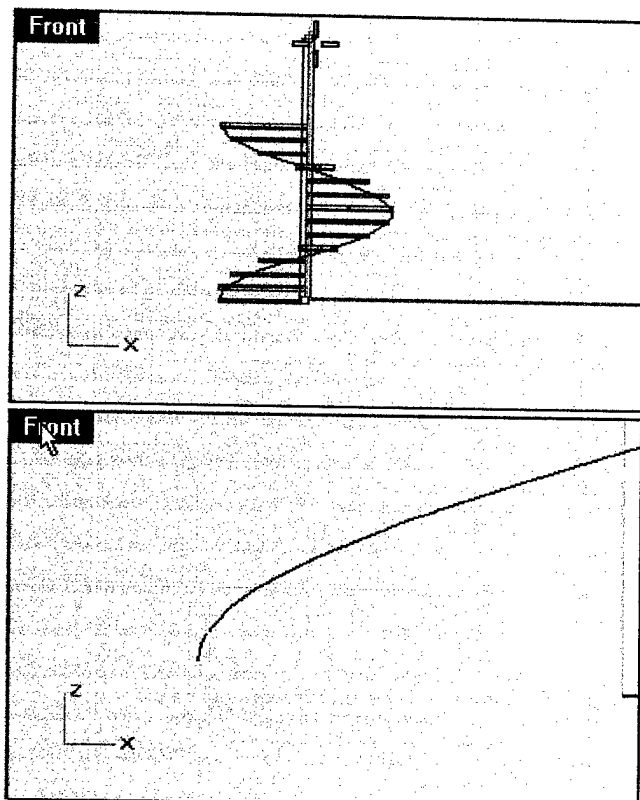
Now use Solid/Extrude Planar Curve at a thickness of .2 units to create a step, then delete the surface, or use Extrude on the edges, Join the pieces and then use Solid/Cap Planar Holes.



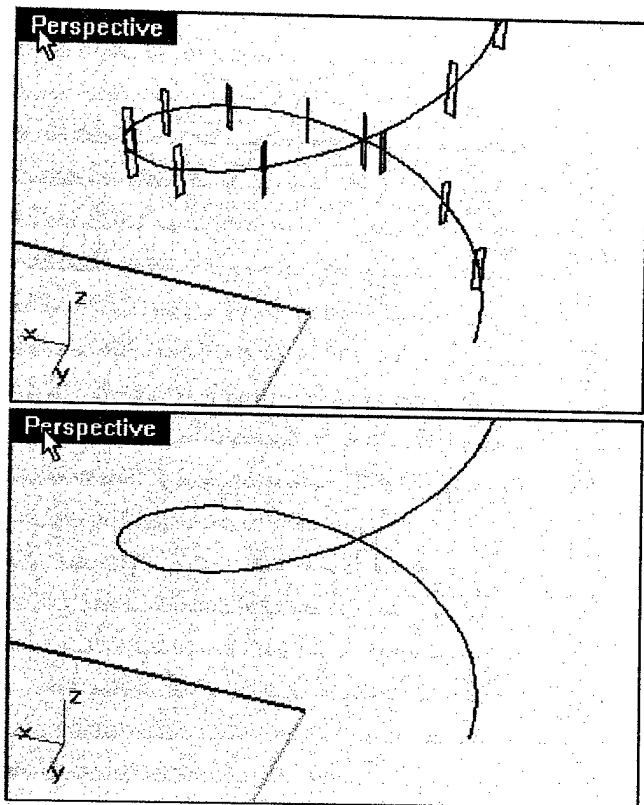
This Helix will be used allot. Now Array the step using Transform/Array/Along Curve, keep it to 14 pieces.



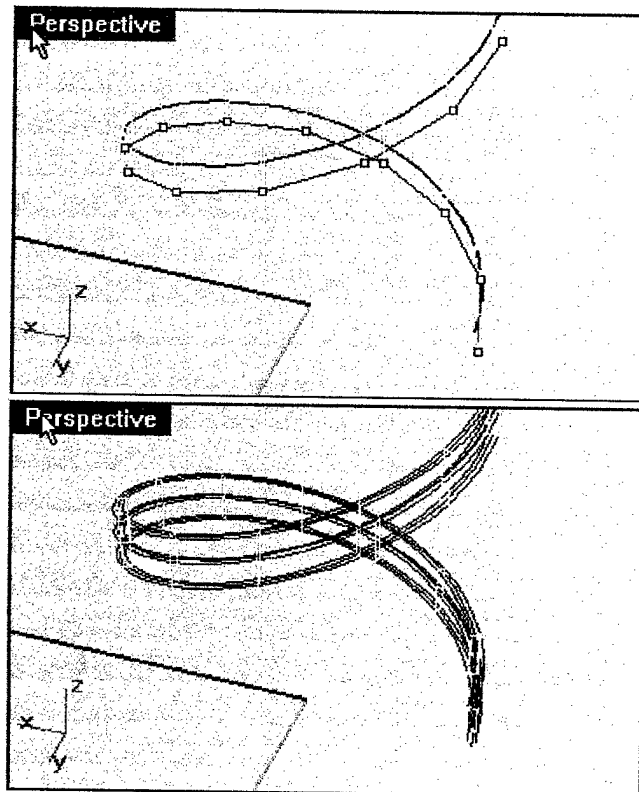
Now create a center shaft using Solid/Tube. Put a Sphere at the top to round it off. You can use the tube to cut the sphere in half, then join them. Next create a Rectangle at the base helix (.2 x 1.125 .175 from the top line). This will be the rail that holds the steps.

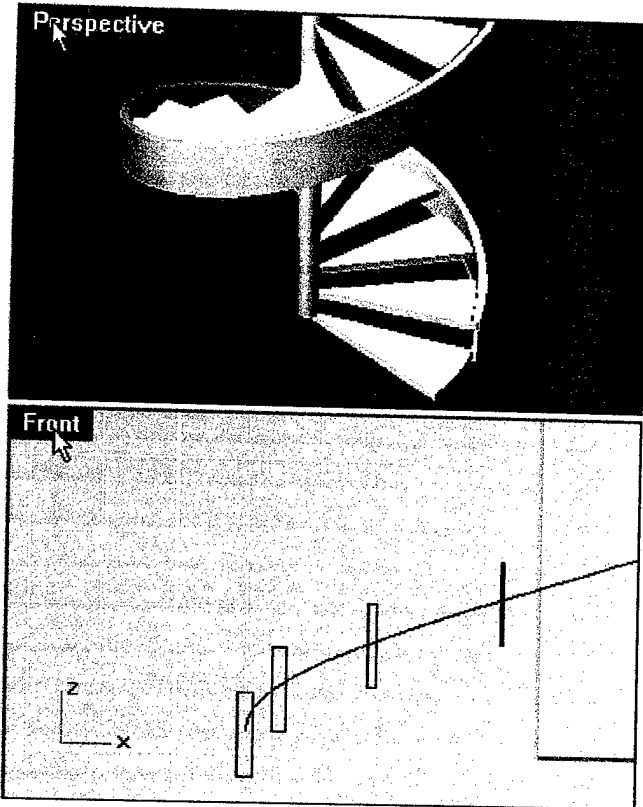


Now do another Transform/Array/Along Curve. A sweep is not possible in my experience because the rail will distort and be uneven, so creating an array will create a clean loft.

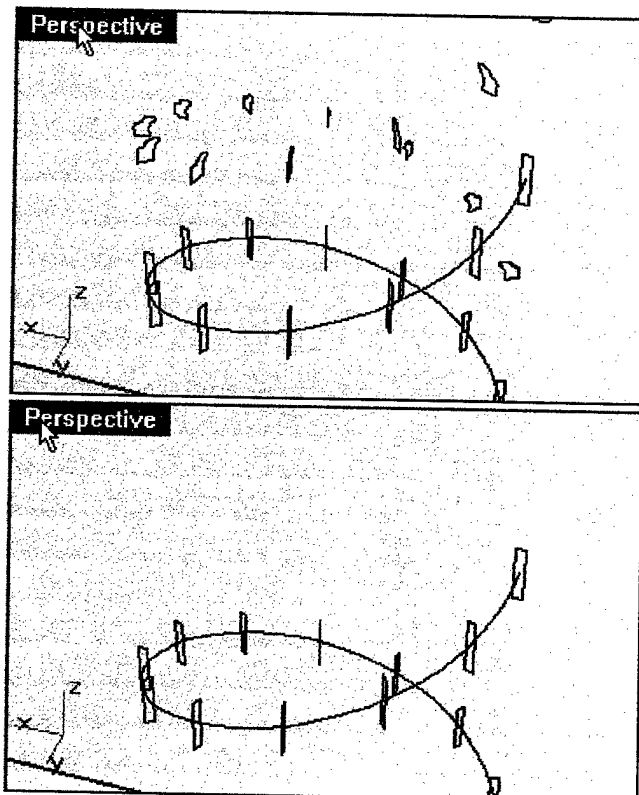


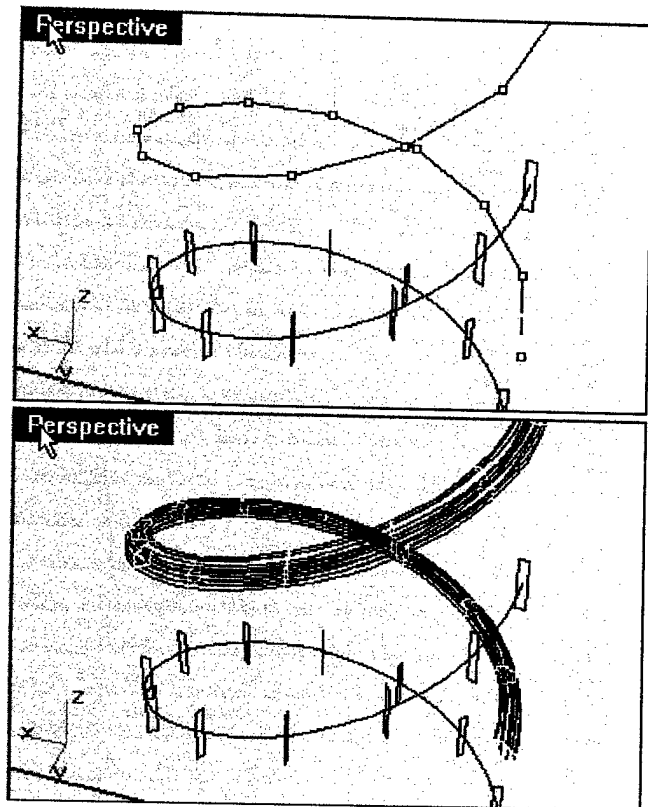
So highlight the segments and use Surface/Loft. When using loft, use Cap Planar Curves to cap the ends.



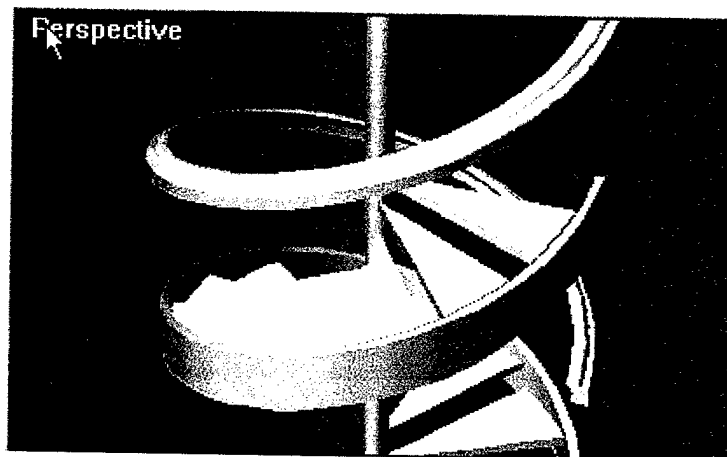



Next we create a banister. There are many moldings of banisters, this one I made from a book. Use the Array again as you did for the lower rail.

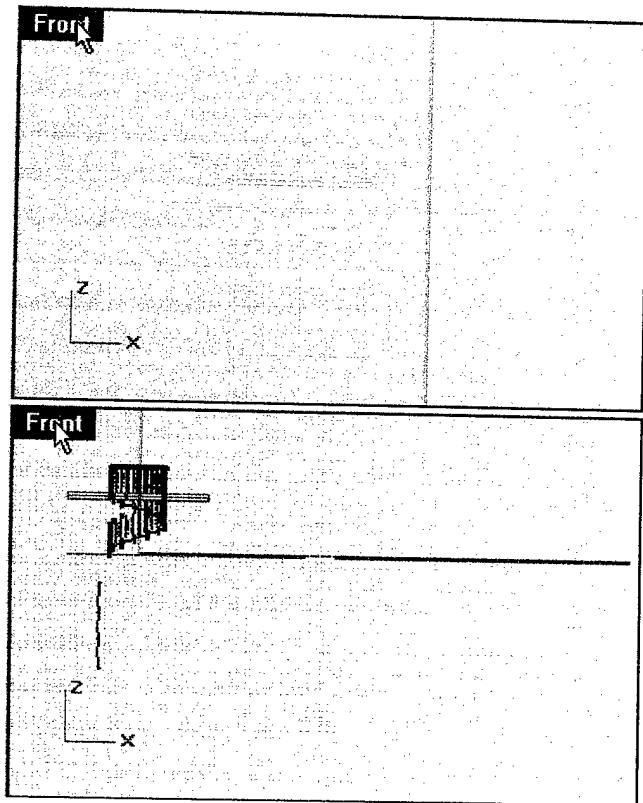




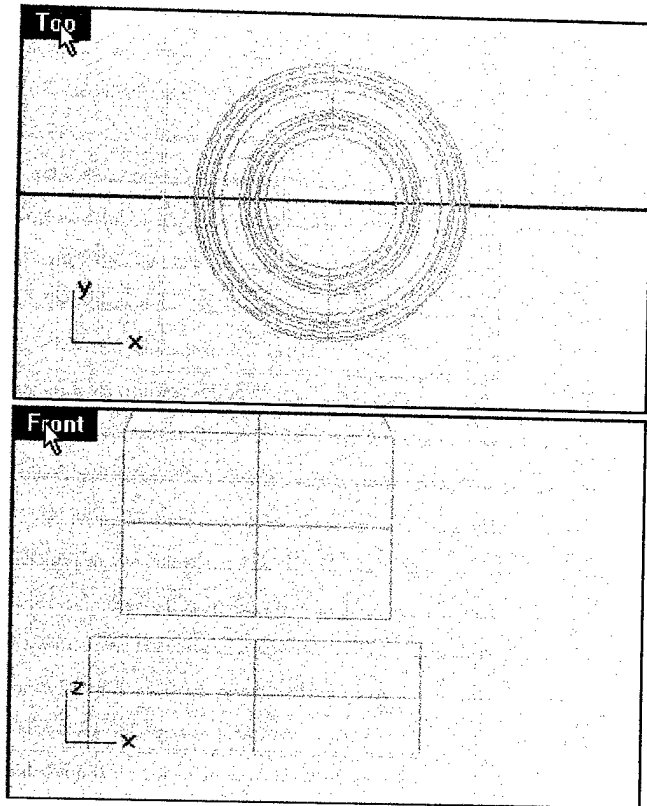
And here we have the simpler parts of the stairs. When you create Lofting, using custom points will determine how accurate the details are. Best is to experiment with 10, 20, 30 and "not simplified". Here I use Not simplified so the best detail can be shown. This will create a bigger file.



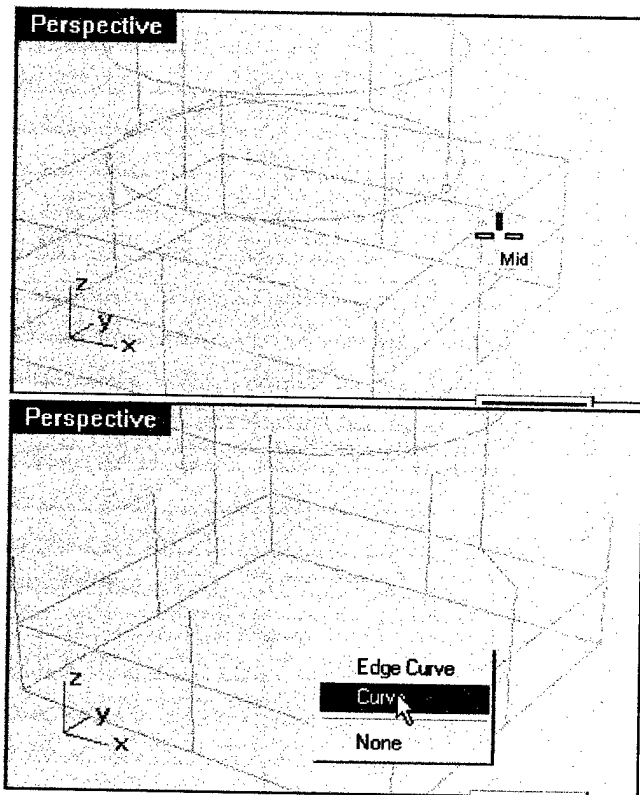
Here we will create the banister post. Click on the second picture to get a larger version. Here I did a line segment then revolved  it and created the square base afterwards.

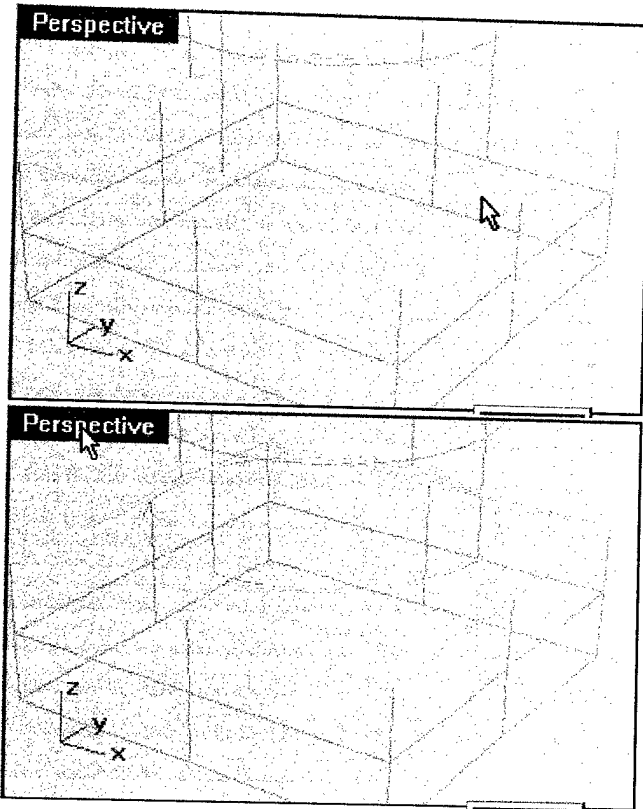


Looking at the top of the post create a Square  to be use as a base by Extruding. Next line up the base as show.

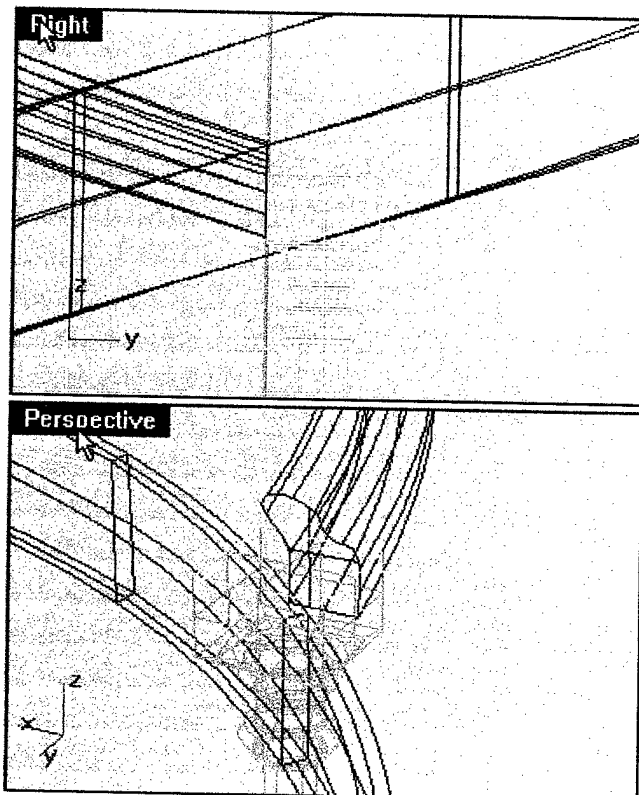


Create a line segment between the 2 objects using Snap Mid to line it up. Then use Sweep 2 Rails.

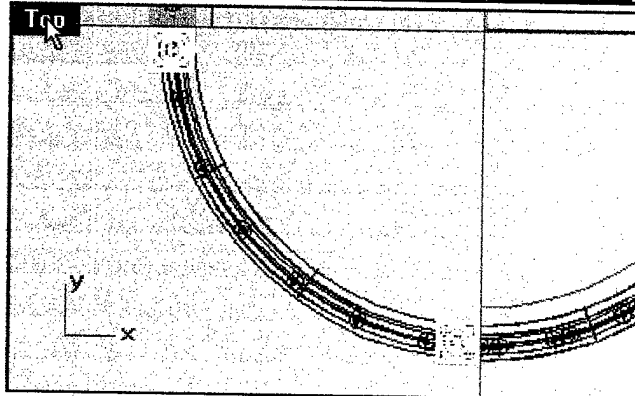
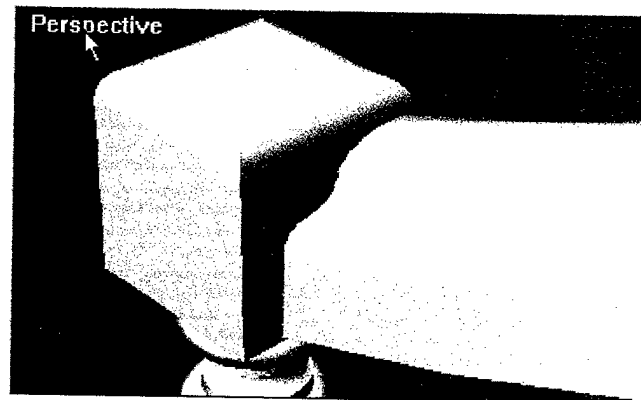
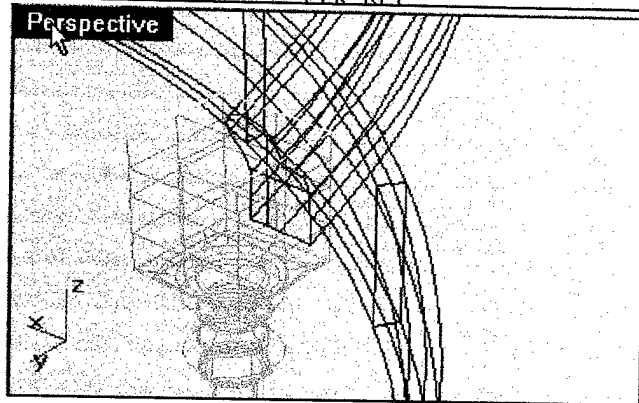
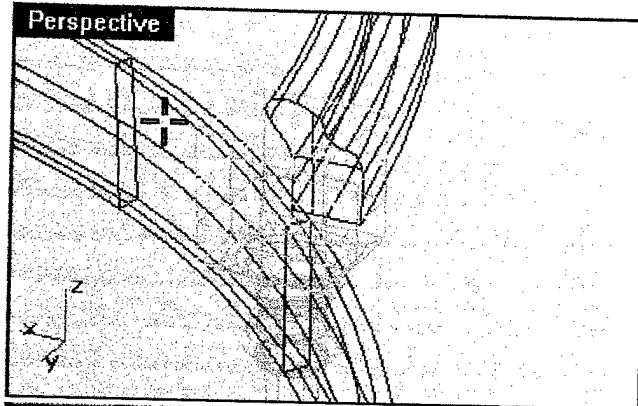




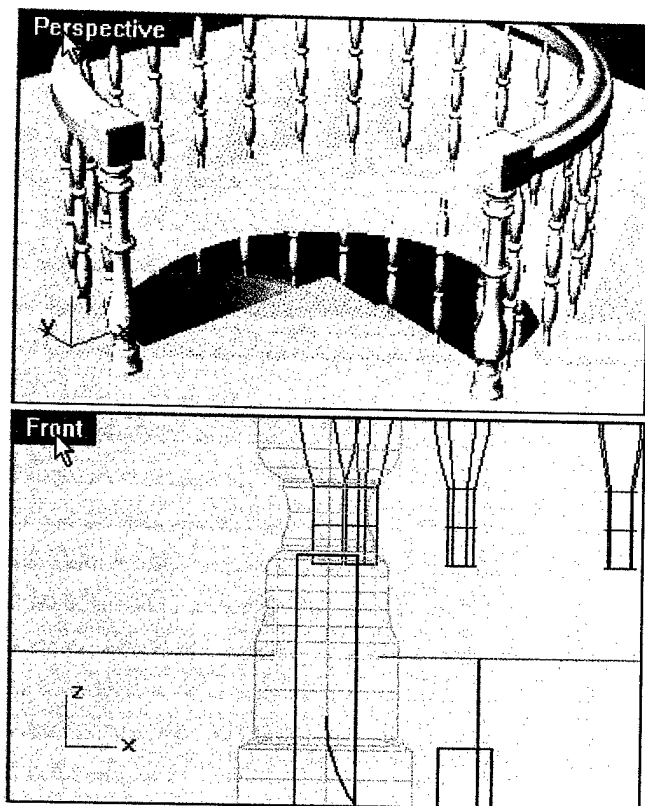
Next scale the post so it lines up from the floor to about where it is shown. What I did is put a cap on top and Fillet the edge.



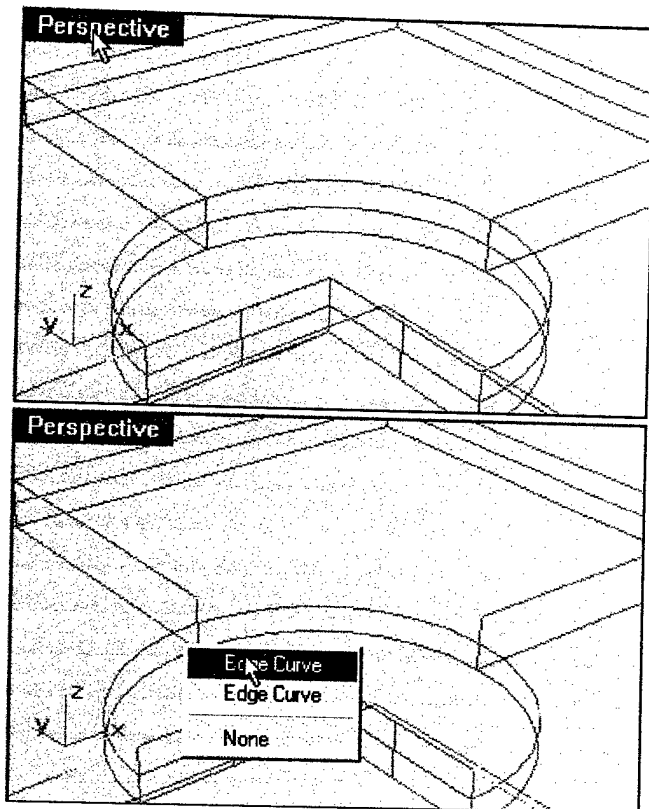
Use Extrude Planar Curve to create the cap and then use Solid/Fillet at .1 unit to bevel the edge.




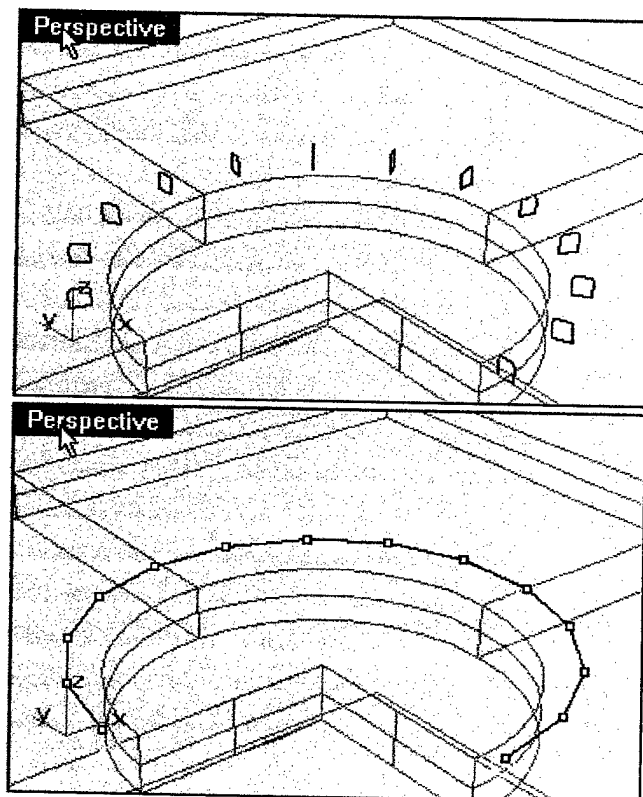
Next use Copy to create 2 posts at the end of the banisters on the second floor. The scale will be dealt with later.

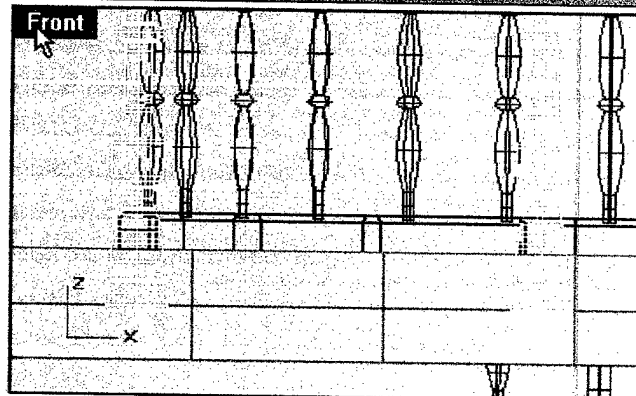
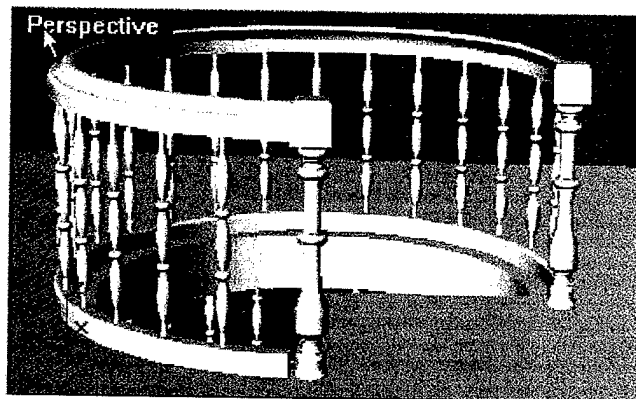
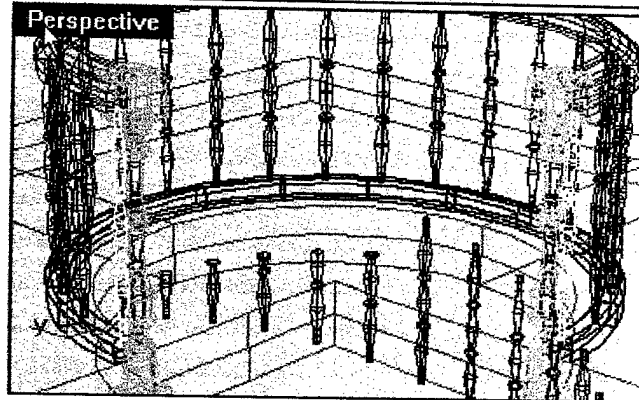
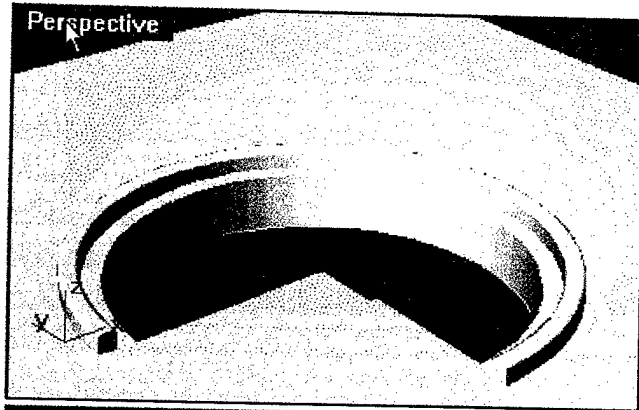


Next we will create a rail at the base of the spindles. I used a square then filleted the segment at .05 units and then scaled it down to this size.

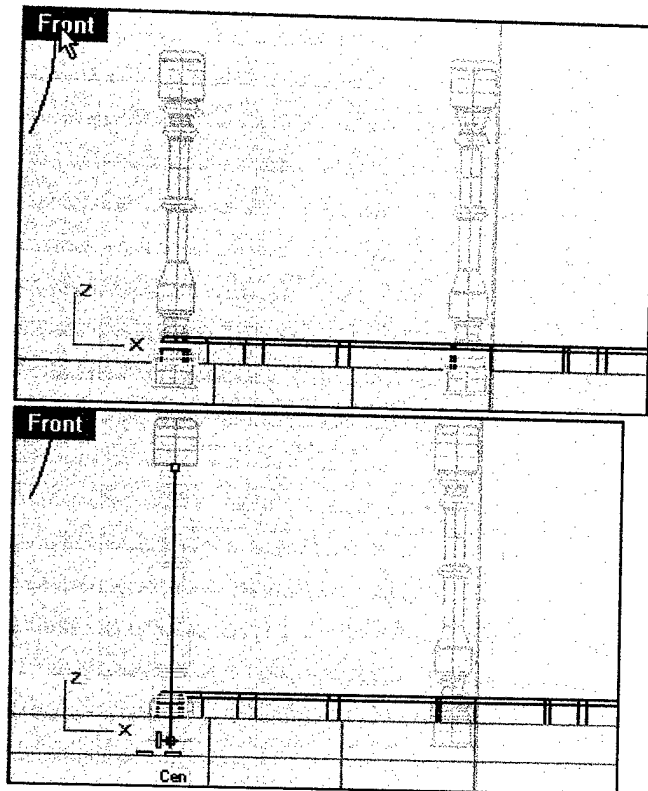


Use the Array to duplicate the pattern and then Loft 

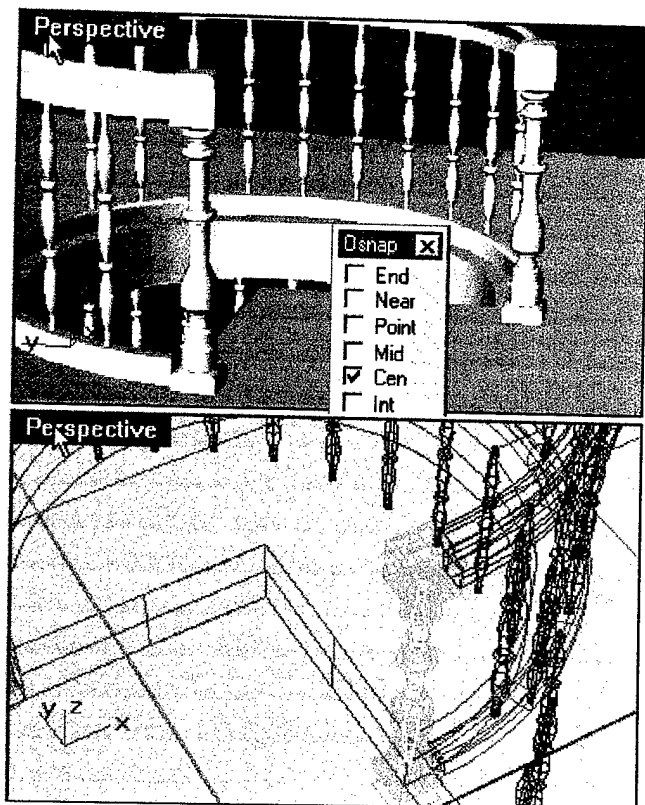




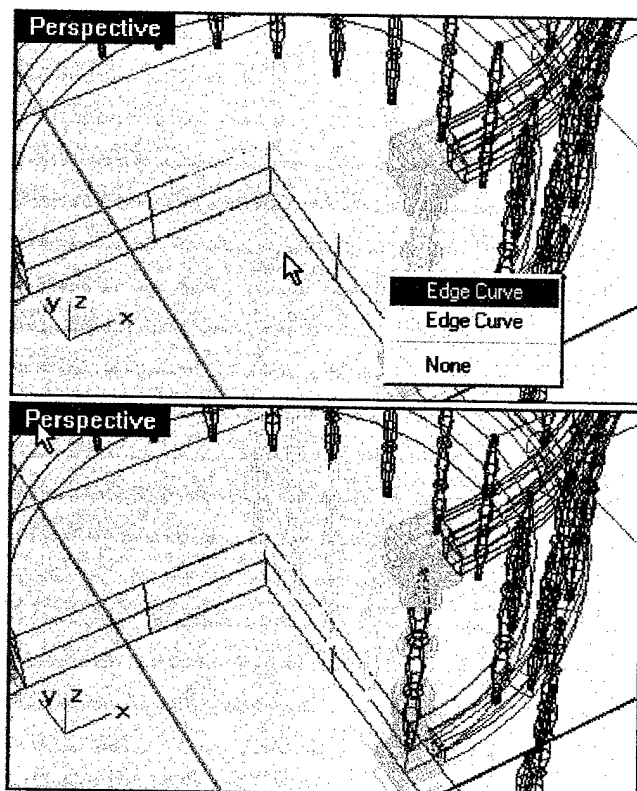
Now to scale the post, move the base block to line up with the floor. Then use Snap Center at the same time you use Scale 3D. select the top center of the post as shown then the bottom center. Move it up and align it with the center of the lower block.



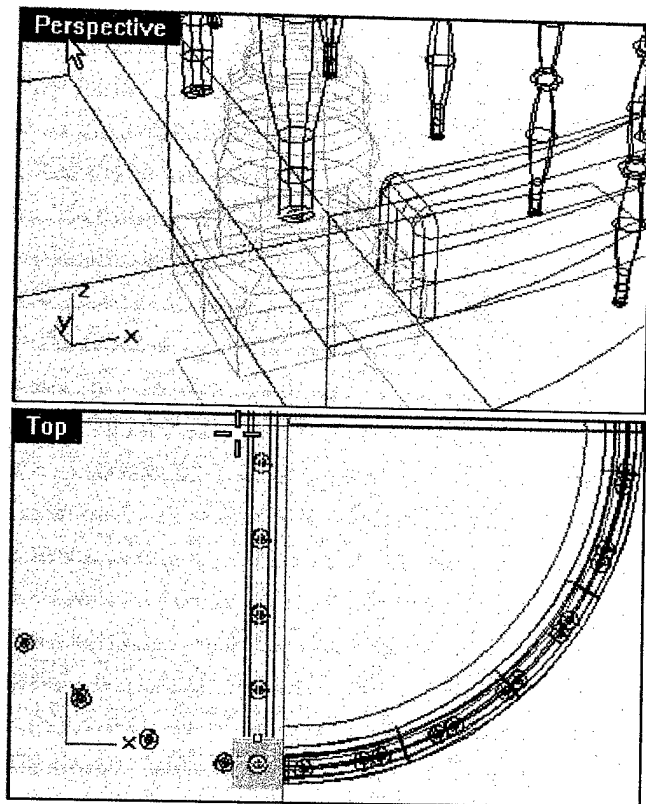
Now the pieces are proportionate.



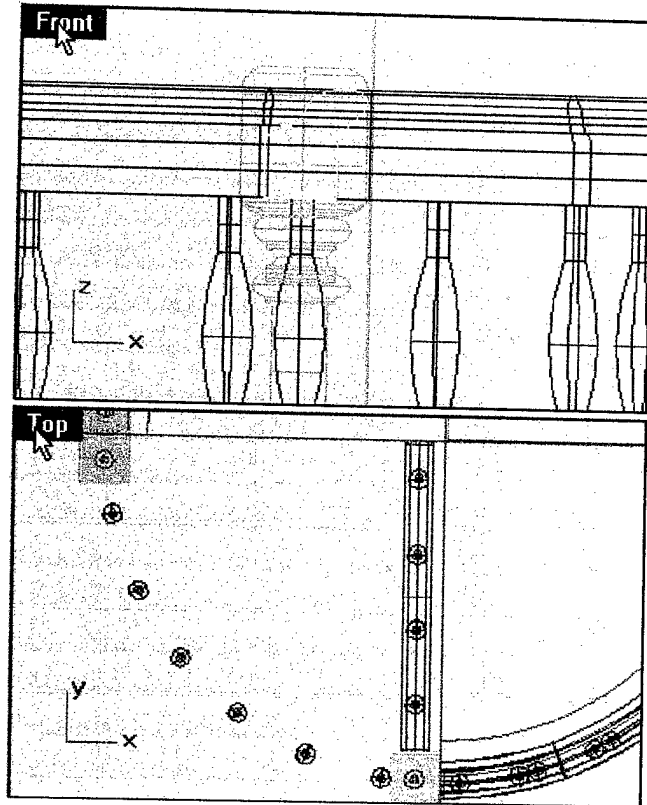
Next create an Array of spindles along the edge of the hole using 5 objects starting with the spindle that's in the banister post.



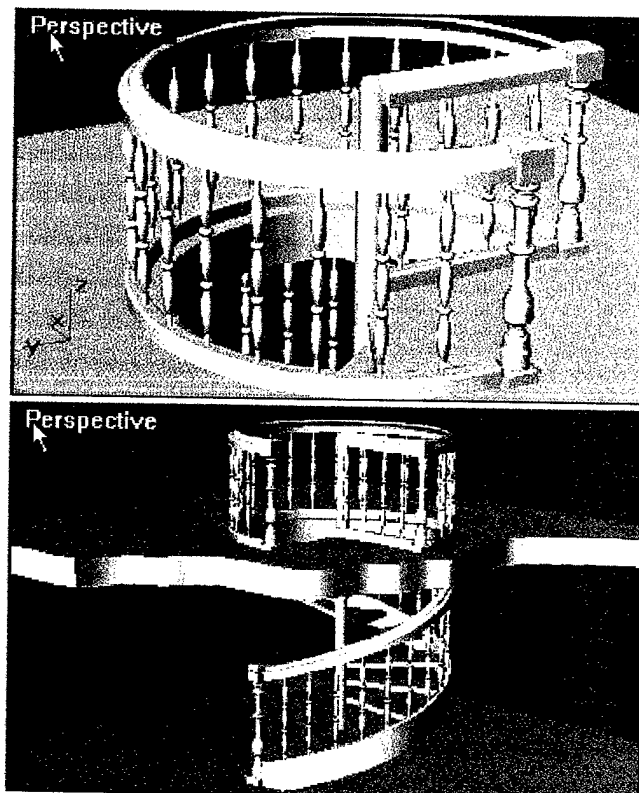
Next copy the floor base pattern as you made before and line it up as shown. Use Extrude Planar Curve to extrude it to the edge of the hole. Then Fillet the upper edges using .05.



Next do the same with the banister pattern.



Here you see the final render. Click on second picture for larger picture.



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